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The role of science, technology and innovation in increasing substantially the share of renewable energy by 2030

Report of the Secretary-General

Executive summary

This report focuses on how science, technology and innovation can help increase the share of renewable energy in the global energy mix. It reviews the latest trends in the use of renewable energy technologies, identifies the barriers and drivers of their deployment and provides an overview of emerging technologies. The report also discusses some of the key issues in the use of renewable energy, including market and policy design, technical challenges in integrating renewables in the electricity grid, off-grid and mini-grid applications, and the use of renewables in households. The report emphasizes that countries will have different national renewable pathways, depending on contextual factors and priorities. It argues that policy mixes are necessary to support renewable energy deployment. It concludes by underscoring the key role of international cooperation in knowledge sharing, policy learning, capacity-building and technology development, and in improving the interconnection of grid infrastructures.

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Introduction

1. At its twentieth session in May 2017, held in Geneva, Switzerland, the Commission on Science and Technology for Development selected "The role of science, technology and innovation in increasing substantially the share of renewable energy by 2030" as one of its priority themes for the 2017–2018 intersessional period.

2. The secretariat of the Commission convened an intersessional panel from 6 to 8 November 2017 in Geneva, to contribute to a better understanding of this theme and to assist the Commission in its deliberations at its twenty-first session. This report is based on the issues paper prepared by the Commission secretariat,[1] the findings of the panel, country case studies contributed by Commission members, relevant literature and other sources.

3. This report identifies, analyses and presents for discussion key issues concerning the role of science, technology and innovation in increasing substantially the share of renewable energy in the global energy mix by 2030, particularly in developing countries. The report highlights Member States' contributions on good practices and lessons for applying science, technology and innovation to increase the deployment of renewable energy technologies. Chapter I introduces challenges and recent global trends in renewable energy deployment, technological and non-technological barriers and drivers of deployment, and emerging technologies. Chapter II presents key issues related to innovation and deployment of renewable energy technologies. Chapter III highlights how policymakers can harness science, technology and innovation to increase the share of renewable energy. Chapter IV presents findings and suggestions for consideration by Member States and other relevant stakeholders.

I. Background and context

A. Clean energy as a cross-cutting issue for sustainable development

4. It is estimated that 1.1 billion people in the world today have no access to electricity. This is 14 per cent of the world's population. Some 85 per cent of those without access to electricity live in rural areas, mainly in Africa. Furthermore, 2.8 billion people do not have access to clean forms of energy for cooking.[2] Using traditional biomass and inefficient technologies has serious health, social and environmental consequences. Increasing access to clean forms of energy makes a critical contribution to achieving the 2030 Agenda for Sustainable Development and the Sustainable Development Goals, agreed in September 2015. Goal 7 aims primarily to ensure universal access to affordable, reliable, sustainable and modern energy services by 2030. Within this, there is a target "to increase substantially the share of renewable energy in the global energy mix" by 2030.

5. Achieving universal energy access and increasing renewable energy is likely to have largely positive impacts on other aspects of sustainable development and other Goals.[3] The reduction of poverty (Goal 1) requires, among other things, the development of modern infrastructures. Renewable energy can play an important role in the development of such infrastructures. In addition, it is critical for productive capacities and the creation of income generation opportunities, as highlighted by recent UNCTAD research.[4] Renewable energy can also contribute to good health and well-being (Goal 3) by reducing the health risks

[1] The issues paper and all presentations and contributions to the intersessional panel cited in this report are available at http://unctad.org/en/pages/MeetingDetails.aspx?meetingid=1562.

[2] International Energy Agency (IEA), 2017a, *World Energy Outlook 2017* (Organization for Economic Cooperation and Development (OECD), Paris).

[3] International Council for Science, 2017, A guide to SDG [Sustainable Development Goal] interactions: From science to implementation.

[4] UNCTAD, 2017, *The Least Developed Countries Report 2017: Transformational Energy Access* (United Nations publication, Sales No. E.17.II.D.6, New York and Geneva).

associated with pollution by replacing the use of fossil fuels for cooking and lighting in homes, for example. It is also relevant for gender equality (Goal 5). By replacing traditional forms of energy such as wood fuel, modern forms of renewable energy can reduce the time spent gathering wood by women and girls.[5] Lighting through renewable energy systems can also provide greater time flexibility for domestic activities, especially for women.[6] Furthermore, there are clear synergies with industry, innovation and infrastructure (Goal 9), as well as climate action (Goal 13). Many national innovation policies and international initiatives include a focus on renewable energy technologies, and the expansion of renewable energy is part of most national strategies to mitigate the greenhouse gases that cause climate change.

B. Global trends in renewable energy deployment

6. Recent efforts to increase the use of renewable energy sources have been driven by the following interrelated needs: to improve energy security and diversify energy sources, encourage sustainable economic development and protect the climate and the environment from the impacts of fossil fuel use.[7] These motivations led to a step change in the development and deployment of a range of renewable energy technologies. In addition, policy interventions contributed to dramatic costs reductions of some renewable electricity technologies and the rapid deployment of these technologies.

7. The source of renewable energy can be solar power, wind power, geothermal power, hydropower and biomass. Accordingly, technologies are diverse and can be differentiated by their nature – variable or dispatchable, centralized or distributed, direct or indirect and traditional or modern.[8] Some renewable energy sources and technologies, such as traditional biomass that involves the direct – and often inefficient – combustion of wood and charcoal, are not considered "clean". Renewable energy can play an important role across the entire energy system. It can be used for electricity generation, transport, heating and cooling or cooking. Renewable energy sources have been used for as long as energy systems have existed and predated the use of fossil fuels.

8. In absolute terms, the contribution of renewable energy to the world's total primary energy supply has increased significantly in the last decades – from 1,121 million tons in 1990 to 1,823 million tons in 2015. However, its share thereof increased to a smaller extent, from 12.8 per cent in 1990 to 13.4 per cent in 2015.[9]

9. According to IEA,[10] renewable energy accounted for 14 per cent of global primary energy demand in 2016 (9 per cent, if traditional forms of solid bioenergy are excluded). The power sector is the principal user of renewable energy, representing almost 60 per cent of its use. Twenty-four per cent of electricity now comes from renewables worldwide: 16 per cent, from hydropower; 5 per cent, from wind, geothermal, solar and tidal power combined; and 2 per cent, from bioenergy and waste. Renewables supply 9 per cent of heat demand in industry and buildings, while the proportion in transport is much smaller, at 3 per cent. Most of the latter is biofuels.

10. Regional figures on the use of renewable energy show significant variation between different countries. This is because the use of renewable energy largely depends on contextual factors such as geographical and environmental conditions, socioeconomic and development priorities, cultural and institutional conditions, and policy and regulatory frameworks. In OECD countries, the share of renewable energy in the total primary energy supply was 9.6 per cent in 2015. In comparison, the share of renewables was 40 per cent in

[5] S Oparaocha and S Dutta, 2011, Gender and energy for sustainable development, *Current Opinion in Environmental Sustainability*, 3(4):265–271.

[6] M Millinger, T Mårlind, and EO Ahlgren, 2012, Evaluation of Indian rural solar electrification: A case study in Chhattisgarh, *Energy for Sustainable Development* 16(4):486–492.

[7] IEA, 2011, *Renewable Energy: Policy Considerations for Deploying Renewables* (OECD/IEA, Paris).

[8] IEA, 2016, *World Energy Outlook 2016* (OECD/IEA, Paris).

[9] OECD, 2018, OECD Data, Renewable energy, available at https://data.oecd.org/energy/renewable-energy.htm (accessed 7 March 2018).

[10] IEA, 2017a.

Brazil, 8 per cent in China and 25 per cent in India. The use of renewable energy in developing countries is often dominated by traditional forms of bioenergy. The share of renewables in total primary energy supply varies considerably – from 28 per cent in Viet Nam, to 53 per cent in Costa Rica and 81 per cent in Kenya.[11]

C. Technological and non-technological barriers and drivers in renewable energy deployment

11. In recent years, there has been fast progress in the deployment of some renewable energy technologies. The range of factors that have promoted or inhibited renewables development and deployment are both technological and non-technological in their nature and include costs and affordability, financing, technical maturity, integration into electricity systems, environmental sustainability and skills.

12. Until recently, the costs of renewable technologies have usually been higher than those of fossil fuels. The gap has now started to close, especially for solar photovoltaics and wind energy, driven by cost reductions and deployment incentives implemented in an increasing number of countries. For example, between 2008 and 2015, the average costs of solar photovoltaic energy decreased by almost 80 per cent, while those of land-based wind energy declined by 35 per cent.[12] On the other hand, the current costs of off-grid and mini-grid solutions often make these technologies unaffordable for rural communities in many developing countries.

13. Cost reductions and decades of policy support in a number of countries have created a favourable investment climate for some renewable energy technologies. Investment in renewable energy has almost doubled since 2007 – from $154 billion to $305 billion (2015). In 2015, global investment in renewable energy was mostly due to solar photovoltaic and wind energy, which accounted for around 90 per cent.[13] However, finance has been a significant barrier to deployment in many countries and has required policy intervention to provide greater certainty for investors. It remains a major challenge in many developing countries.

14. Solar power, hydropower and wind power are now considered well-established technologies. However, some technologies, such as geothermal energy or bioenergy, are not yet ready to be widely deployed and require significant development and demonstration before reaching adequate levels of reliability and cost-effectiveness. South Africa, for example, has a demonstration project that is examining the commercial viability of growing algae and converting it into energy products.[14] Furthermore, renewable technologies sometimes present new challenges – such as bottlenecks in network infrastructure and limits to the ability to absorb variable renewables – to electricity systems and markets.

15. Non-technological barriers include concerns about environmental sustainability that have led to controversy about the use of some renewable energy sources. There are pertinent questions, for example, about the following issues: the use of first-generation biofuels with respect to life-cycle emissions and implications for land use; the impacts of large hydropower plants on regional ecosystems; the lack of appropriate skills and capabilities to install, operate and maintain renewable energy technologies; and the lack of awareness of renewable energy solutions. In addition, the deployment of renewable energy technologies and the design of policies to encourage this require new skills and capabilities.

[11] IEA, 2017b, *Renewables Information 2017* (OECD/IEA, Paris).

[12] IEA, 2016, *Next-Generation Wind and Solar Power: From Cost to Value* (OECD/IEA, Paris).

[13] International Renewable Energy Agency, 2017a, *Rethinking Energy 2017: Accelerating the Global Energy Transformation* (Abu Dhabi).

[14] Contribution from the Government of South Africa, available at http://unctad.org/meetings/en/Contribution/CSTD_2018_IPanel_T1_RenewableEnergy_con10_SouthAfrica_en.pdf (accessed 6 March 2018).

D. New and emerging renewable energy technologies

16. There remains significant scope for innovation that can further improve and reduce costs of renewable energy technologies. This can include material science in solar photovoltaic cells, the integration of electric vehicles into the power grid and enabling digital technologies into the energy systems.

17. While silicon-based solar photovoltaic energy is likely to remain dominant, a promising variety of third-generation thin film cells based on Earth-abundant materials[15] is emerging in material science. Perovskite solar cells, for example, have excellent light-absorbing capacities and lower manufacturing costs – photoelectric efficiencies improved from 10 per cent to over 20 per cent between 2012 and 2015. However, perovskites are still in the early stages of research and development, with uncertainty regarding long-term stability and feasibility for large-scale deployment.[16] Third-generation solar photovoltaic cells are aiming for combinations of high-power conversion efficiency, lower cost and usage of materials, and lower manufacturing complexity and costs. Achieving all three objectives remains elusive, but with greater efforts into research and development, solar photovoltaic technology can achieve an even larger scale of deployment.

18. Another emerging area in renewable energy deployment is integration into smart infrastructures, such as vehicle-to-grid integration. On average, personal vehicles are on the road for about one hour a day, while the rest of the day, they are stationary – in parking lots or garages, near buildings with electrical power.[17] There is a growing interest in developing vehicle-to-grid systems that provide a bi-directional electricity flow between a vehicle and the power grid. There is a possibility of using electric vehicles as storage devices, with the potential of selling electricity back to the grid during peak demand while the vehicles are not being used. Numerous benefits can include new business models that can incentivize owners with additional revenues, scaling application of electric vehicles beyond individual use and integration into smart infrastructure and cities. One of the motivations for using electric vehicles is the increasing trend of countries to phase out petrol and diesel vehicles. For example, India plans to do so by 2030; China, France and the United Kingdom of Great Britain and Northern Ireland, by 2040.[18] Several other countries have different target dates for the phase-out.[19]

19. As renewable energy technologies increasingly rely on digital technologies, a key future research area is the digitalization of energy systems that become more connected, intelligent, predictable and sustainable. Transport infrastructure and electric vehicles are being increasingly used as leverage for automated, connected, electric and shared mobility. Smart power grids can match and integrate intermittent sources of electricity such as solar and wind power with transport systems on a wide scale, owing to the cross-sectoral nature of mobility. Potential benefits include greater energy efficiency and optimized energy consumption. However, automated, connected, electric and shared mobility is dependent on consumer acceptance, policy measures and technological progress.[20]

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[15] For example, copper zinc tin sulphide, perovskite solar cells, nanomaterials such as organic solar photovoltaic cells and quantum dot solar cells.

[16] Massachusetts Institute of Technology, 2015, *The Future of Solar Energy*, Energy Initiative.

[17] BK Sovacool, J Axsen and W Kempton, 2017, The future promise of vehicle-to-grid (V2G) integration: A sociotechnical review and research agenda, *Annual Review of Environmental Resources*, 42(1):377–406.

[18] World Economic Forum, 2017, Countries are announcing plans to phase out petrol and diesel cars. Is yours on the list? 26 September.

[19] IEA, 2017c, *Global EV Outlook 2017: Two Million and Counting* (OECD/IEA, Paris).

[20] IEA, 2017d, *Digitalization and Energy* (OECD/IEA, Paris).

20. Digital technologies are also relevant for buildings, which account for more than 50 per cent of electricity demand. Energy in buildings is generally used for heating, cooling and lighting. Digital technologies are contributing to improved energy response through real-time data by using sensors, which can be managed and monitored through smart devices. Predictive user behaviour, which utilizes learning algorithms, is another emerging technology that can effectively balance energy loads between consumer demand and utility supply. However, the potential impact of greater connectivity of energy systems is still uncertain because of perceived consumer reservations on data privacy, cybersecurity and implications for employment due to automation.

II. Key issues in the innovation and deployment of renewable energy technologies

21. The following section focuses on issues in the innovation and deployment of renewables. These issues are not isolated, but rather interrelated. The deployment of renewable energy technologies involves an innovation system, comprising technological and non-technological contextual factors, and this requires a mix of policies as nations identify the most appropriate renewables deployment pathway to their conditions.

A. Renewable energy market and policy design

22. Technological innovation can be accelerated by both international competition and cooperation. An important aspect of policymaking is to recognize the value of both, and the benefits of encouraging them as appropriate in different circumstances. International interactions within the innovation chain of a renewable technology can allow economic specialization – in manufacturing for example – resulting in efficiency benefits for all countries involved. It might also enable countries without a fully developed innovation chain to begin activities further along the chain. However, the internationalization of the innovation system can also create tensions, given that competition is a key feature of international trade, and the success of a sector in one country can spell demise for the same sector in another country.

23. For some countries, the near-term priorities may be to provide energy access to improve people's health, well-being and opportunities for income-generating employment. The benefits of providing this access as soon as possible may present compelling reasons for accessing international innovation supply chains to use already developed technology and intellectual property, so that technologies can be rolled out quickly, rather than waiting several years for the innovation chain to be built up domestically.

24. On the other hand, a longer-term perspective might consider the economic and industrial strategy of a country over decadal time frames. Such a perspective might also consider that building up more elements of the innovation supply chain domestically could in the longer term generate greater benefits for the economy as a whole, through employment creation and associated macroeconomic stimulus. The example of the development of solar photovoltaic energy markets in box 1 shows that innovation in renewables is highly international, with drivers in one country having the potential to produce a significant impact on others.

Box 1
Market designs in developing solar photovoltaic markets: Case studies

When China started developing its solar photovoltaic industry, it did not own any designs. It focused on labour-intensive downstream manufacturing, rather than domestic research and development. During the 2000s, the country's approach to photovoltaics was production based and export driven, aiming at markets that provided strong incentives for the use of photovoltaics. It supported the manufacturing of photovoltaics through innovation funds, regional investment support policies and loans. More recently, China has begun to manufacture and deploy solar photovoltaic systems on very large scales.

Germany had a different approach. Its investment in the research and development of solar photovoltaic energy began in the 1970s, involving research institutes, universities and industry. Such investment was supported by federal and regional funding. From the 1990s, Germany also acted to create a domestic market for the technology, initially for rooftop installations and then later, larger-scale installations, for example. It introduced feed-in tariffs to further support market creation. In large part due to the activity of Chinese manufacturing, a rapid fall in the global cost of photovoltaic modules took place. Germany responded by reforming its feed-in policy. This has led to a sharp decline in the production and installation of photovoltaic cells.

Sources: S Jacobsson and V Lauber, 2006, The politics and policy of energy system transformation: Explaining the German diffusion of renewable energy technology, *Energy Policy*, 34:256–276; AL Polo and R Haas, 2014, An international overview of promotion policies for grid-connected photovoltaic systems, *Progress in Photovoltaics*, 22:248–273; HJJ Yu, N Popiolek and P Geoffron, 2016, Solar photovoltaic energy policy and globalization: A multi-perspective approach with case studies of Germany, Japan, and China, *Progress in Photovoltaics*, 24:458–476.

25. The policy instrument most frequently used to promote renewable energy has been the feed-in tariff, which guarantees a fixed price per unit of electricity sold over an agreed period. This is an attractive form of price support for renewables, which are typically dominated by high capital costs. Feed-in tariffs have contributed to swift cost reductions of renewables, particularly onshore wind and solar photovoltaic energy. Bulgaria, Germany, Hungary, Japan, Kenya, Portugal, Turkey and the United Kingdom are among those countries that have used feed-in tariff-based approaches.[21] However, the risk of the feed-in tariff is that Governments could lock themselves into subsidising renewables for a long time, which would have an adverse impact on the economy.[22]

26. In this context, tendering or auction-based approaches are increasingly used as policy instruments to identify the price for renewable energy contracts and deliver substantial cost reductions in renewable energy. In many countries, a transition from government-administered feed-in tariffs to auction systems has taken place during the past few years. Chile and Mexico have achieved low prices for solar photovoltaic energy through auctions, while Germany, Japan, Portugal and the United Kingdom have revised their allocation of contracts or tariffs to be delivered on an auction basis. It is expected that almost 50 per cent of all renewable electricity capacity additions will be driven by auctions in the next five years, compared with 20 per cent in 2016.[23]

27. Governments tend to play a crucial role in the innovation and deployment process, for example, by funding research and development, creating demand through deployment incentives, reforming energy markets and setting standards, and implementing other measures to strengthen investor confidence. Mexico, for example, has created and invested in six energy innovation centres focusing on geothermal, solar and wind power; bioenergy;

[21] Contributions from the Governments of Bulgaria, Germany, Hungary, Japan, Kenya, Portugal, Turkey, and the United Kingdom, available at http://unctad.org/en/pages/MeetingDetails.aspx?meetingid=1562 (accessed 6 March 2018).

[22] F Zhang, 2013, How fit are feed-in tariff policies? Evidence from the European wind market, Policy Research Working Paper 6376.

[23] IEA, 2017e, *Renewables 2017: Analysis and Forecasts to 2022* (OECD/ IEA, France).

ocean energy; and smart grids.[24] Furthermore, government incentive systems and procurement policies can also encourage the use of local technology and equipment, such as in the Islamic Republic of Iran.[25] In general, Governments can play an important role in providing a legal and regulatory structure, which ensures that private sector activities are being directed in a way that is beneficial for society and provides clarity and confidence to players in the private sector.

28. Financing is an important factor in the deployment of renewable energy technologies. Box 2 describes the different roles that public, private and institutional investors can play in financing renewable energy.

Box 2
Landscape of financing renewable energy deployment

Public finance institutions: Renewable energy has often had to rely on public finance institutions, particularly in early stage project development. Examples include international financial institutions such as multilateral development banks and development finance institutions (the latter are usually bilateral development agencies). Public finance instruments are often in the form of grants, subsidies and guarantees to facilitate renewable energy projects that are too risky for private sector support.

Private investors, including new capital market instruments such as green bonds: Green bonds are gaining prominence as innovative mechanisms attracting finance for renewable energy projects in emerging economies. Green bonds are any type of bond instrument to fund projects that have a positive environmental and climate impact. They can be used to raise large-scale long-term financing from non-bank sources and at relatively low cost.

Institutional investors, including pension funds: Institutional investors are a major potential source of capital for renewables. Institutional investors such as pension funds from developed economies show increasing interest in investing in developing countries.

Sources: International Renewable Energy Agency, 2016, *Unlocking Renewable Energy Investment: The Role of Risk Mitigation and Structured Finance* (Abu Dhabi); and 2017a.

B. Technical challenges of integrating renewable energy to electricity grids

29. As more renewable energy is deployed, the technical and economic aspects of integrating larger shares of renewables into electricity grids becomes increasingly challenging. There is a major emphasis on innovation in enabling technologies that can help integrate variable renewables into electricity systems, including storage; smarter electricity systems that include the widespread integration of digital and so-called exponential technologies such as artificial intelligence; and technologies to increase the flexibility of energy demand.

30. Storage is a key enabling technology. Yet storage technologies vary significantly in terms of output, rates of charge and discharge, and the length of time they can store energy. Current battery technologies are unlikely to be sufficient to deliver large-scale seasonal storage so that solar electricity can be stored in summer to heat buildings in winter. Therefore, there is a need for advances in other types of heat or energy storage that can operate over longer timescales. Likewise, a range of storage technologies are being developed, with applications ranging from small-scale applications to grid-scale applications, and from rapid-discharge applications to interseasonal storage applications.

[24] Contribution from the Government of Mexico, available at http://unctad.org/meetings/en/Presentation/cstd2017_p07_Mexico_en.pdf (accessed 6 March 2018).

[25] Contribution from the Islamic Republic of Iran, available at http://unctad.org/meetings/en/Contribution/CSTD_2018_IPanel_T1_RenewableEnergy_con05_Iran_en.pdf (accessed 6 March 2018).

31. The mix of variable and dispatchable renewable energy depends on a country's availability of resources and consumption patterns. In Portugal, for example, hydropower and wind power play a significant role in the country's power mix. On average, renewables provide more than 60 per cent of its electricity mix over a year – in 2017, there were six consecutive full days during which renewables provided 100 per cent of the country's electricity.[26]

32. Renewable energy is site specific, and solar- or wind-rich areas can be distant from where the demand is located. Therefore, infrastructure development is important for electricity systems. Such infrastructures are noteworthy investments, and once in place, have a considerable limiting and directing influence on the evolution of the supply and demand balance in a power system. The future of the power grid infrastructure therefore becomes a major issue in countries that have historically invested in a power grid based around the locations of supply and demand in a largely fossil-fuel-based system, but whose plans to transition to a renewables-intensive system means that the location of power generation will substantially change (see box 3).

33. Infrastructure development is also important when related to the different types of renewables, such as centralized versus distributed renewables. Centralized electricity systems are grid bases that require extensive transmission and distribution infrastructures. Conversely, decentralized systems are smaller in scale (for example, mini grids or standalone systems) and have shown to be more appropriate for remote, harder-to-reach rural areas. For example, solar home systems are highly decentralized, while large-scale hydropower technologies are used in some of the largest power plants in the world. These factors in turn influence the scale of renewables that are deployed from bottom-up off-grid applications (for example, solar home systems) to larger grid-scale power plants (for example, hydropower plants, concentrated solar power plants or geothermal plants).

Box 3
Adapting grid infrastructure to renewable energy deployment: Case studies

In Germany, the electricity transmission network is facing a challenge: there is significant wind power potential in the north of the country, but the major demand centres are in the south. This means that deploying wind power in the windiest northern regions will entail a huge power flow from north to south during times of high wind and high demand. As a result, the country's energy transition (*Energiewende*) also includes plans to upgrade the grid infrastructure. However, this is not without its challenges, as public acceptance is more amenable to underground cables for the electricity superhighways, resulting in increased costs.

In Japan, part of the Fukushima innovation coast framework is to expand power lines to gain access to wind-rich areas.

The United States of America is also making efforts to modernize its grid. The Department of Energy has developed a grid modernization initiative, with activities focusing on the integration of energy efficiency, renewable power and sustainable transportation technologies into the electrical power system. Technologies and techniques required for successful grid integration include the following: improved renewable power forecasting; energy storage technologies; advanced power electronics; grid-responsive building technologies; vehicle-to-grid technologies; and new grid sensing, control and operations approaches.

Sources: Contributions from the Governments of Germany, Japan and the United States, available at http://unctad.org/en/pages/MeetingDetails.aspx?meetingid=1562.

[26] Contribution from the Government of Portugal, available at http://unctad.org/meetings/en/Contribution/CSTD_2018_IPanel_T1_RenewableEnergy_con09_Portugal_en.pdf (accessed 6 March 2018).

C. The role of renewable energy in extending access to electricity

34. Some 1.1 billion people still require access to electricity. A range of evidence suggests that extending electricity access contributes to various improvements in overall socioeconomic development.[27]

35. Rapid technological progress in renewables and cost reductions represent an opportunity for electrification in rural areas – especially in developing countries – through off-grid and mini-grid solutions. According to recent research by UNCTAD, energy access plans and related income-generation opportunities should be fully integrated into a country's overall development strategies through an energy-transformation nexus.[28] In this perspective, supply and demand for energy are tackled holistically and are a means of fostering economic diversification and job creation.

36. Historically, most of the interventions that extend electricity access by renewables have been through grid extension, less so through off-grid technologies. Grid-based solutions typically involve the upfront investments in infrastructure being paid for by the Government or utility company and spread through customer bills. As such, the upfront cost to any individual customer willing and able to connect is relatively low – a small connection charge followed by running costs. However, this kind of top-down approach can take time to reach the whole of society. In such situations, it is possible that off-grid renewables may be able to provide access to electricity to communities faster than grid electrification can manage. IEA[29] has suggested that off-grid solutions, particularly solar photovoltaic technology, are likely to be the most cost-effective solutions for universal electrification in sub-Saharan Africa.

37. Another important consideration in increasing energy access by using renewable energy is affordability. Low-income communities may be unable to pay in advance for the investments required, and investors may be equally unwilling to invest in uncertain returns due to the low density of demand users. New business models can make this viable and conducive to development, for example by using microfinance or pay-as-you-go arrangements to spread these costs. Solar Sister, a non-governmental organization that provides support for women in establishing solar microbusinesses, have effectively used the pay-as-you go model. In some cases, payments for new renewable energy technologies can be structured so they are similar to the costs of the energy sources they are replacing, for example, kerosene.

38. Private sector investors are not always interested in developing off-grid applications in remote areas. One approach to address this issue could be clustering and bundling of projects to achieve scale. Measures to overcome barriers to private sector-led investment in small-scale renewable energy projects may include setting up a robust governance structure with clear regulatory and enabling policy environments, standardized licensing procedures, off-grid tariffs and addressing upfront costs through low-interest credit and microfinancing (box 4).

[27] IEA, 2017f, *Energy Access Outlook 2017: From Poverty to Prosperity* (OECD/IEA, Paris).
[28] UNCTAD, 2017.
[29] IEA, 2017f.

Box 4
Rural electrification in Uganda: Case study

Lessons learned from the rural electrification strategy of Uganda revealed the need for government leadership in financing, building initial infrastructure capacities and promoting electrification-related economic development. Thereafter, it becomes feasible for private investors and commercial financing to take over.

The key risk factor inhibiting the rapid expansion of rural electrification in Uganda was commercial risk. New approaches were needed to build demand and rapidly accumulate customers. Cooperatives and the peer-interest principle proved to be useful concepts.

In addition, the previous set of rural electrification providers were struggling because they were too small. Rural service territories must be sufficiently large to generate revenue levels as needed to meet service providers' financial cost requirements.

Another lesson learned was that planning and management for the renewable energy sector should be centralized, and programme implementation simplified. The best way forward was to centralize authority in the lead entity responsible for the renewable energy sector and ensure that electrification was carried out in harmony with the broader scope of national economic and social development planning. It was also important to adequately coordinate the rural aspect of the nation's electricity infrastructure development with the other power sector functions and entities.

Source: Contribution from the Government of Uganda, available at http://unctad.org/meetings/en/Contribution/CSTD_2018_IPanel_T1_RenewableEnergy_con12_Uganda_en.pdf (accessed 6 March 2018).

D. Using renewable energy in the household sector for cooking

39. Traditional biomass represents 49 per cent of the total renewable energy consumption in the world.[30] Some 2.8 billion people still cook and heat their homes using open fires and simple stoves that burn traditional biomass (wood, animal dung and crop waste) and coal. This has grave health, environmental and social consequences.[31]

40. Sustainable Development Goal 7 is not only about increasing the share of renewable energy from the energy mix, but also about the elimination of traditional, dirty biomass – a pressing issue in many developing countries. Therefore, there is an urgent need to deploy alternatives to the traditional use of bioenergy for cooking and other energy services.

41. There are two approaches to address the issue: to promote more efficient and sustainable use of biomass (for example, by producing and distributing bio-methane from biodegradable waste and syngas from lignocellulosic biomass available locally)[32] or to encourage households to switch to modern cooking fuels and technologies. It has proved difficult to make progress in improving access to clean cooking because of affordability (solid biomass is often free, while improved cookstoves and alternative fuels are not) and cultural resistance (preference for taste of food prepared in traditional ways).[33] Evidence has shown that policies and programmes to address this challenge must be embedded in the social and cultural contexts of the communities they involve and take account of their current energy practices, needs and expectations, and potential for productive uses. The engagement of women in this process is particularly crucial, as they frequently have the main responsibility for household energy-related practices such as fuel

[30] International Renewable Energy Agency, 2017a.
[31] World Health Organization, 2016, Household air pollution and health, Fact Sheet No. 296.
[32] Contribution from the Government of Pakistan, available at http://unctad.org/meetings/en/Contribution/CSTD_2018_IPanel_T1_RenewableEnergy_con08_Pakistan_en.pdf (accessed 7 March 2018).
[33] IEA, 2017f.

gathering and cooking. Women can also be effective trainers and communicators in managing and maintaining new local energy systems.

42. While increasing access to clean cooking facilities may overlap with increasing the deployment of renewable energy, the two objectives are not necessarily aligned in all cases. However, as shown in box 5, some solutions are consistent with the increased deployment of renewable energy.

Box 5
Cooking with renewable energy in Bangladesh: Case study

With support from SNV Netherlands Development Organization and KfW Bank, the National Domestic Biogas and Manure Programme in Bangladesh has installed over 46,000 small-scale biogas systems using animal waste in rural areas. The programme has been supporting the expansion of biogas technology in rural areas, with the ultimate goal of establishing a sustainable and commercial biogas sector in Bangladesh. The biogas produced through these plants is used for cooking and lighting in rural households, but slurry, a by-product of biogas plants, can be also used as an organic fertilizer. The programme is being implemented through a network of 45 partner organizations, including private companies, non-governmental organizations and microfinance institutes. The programme saves 44,300 tons of firewood and reduces the use of 1,400 tons of kerosene every year.

Source: Infrastructure Development Company Ltd. 2014. Biogas and biofertilizer, available at http://www.idcol.org/home/dbiogas (accessed 7 March 2018).

III. Key policy considerations

A. Countries have different national renewable energy pathways

43. A country's renewable energy pathway is an important consideration, because once in place, several mechanisms, such as economies of scale, sunk investments, learning effects, user practices and lifestyles can result in "lock-in" for years, if not decades. This lock-in effect can make pathways difficult to change. Renewable energy pathways and related income-generation opportunities should have a central place in national development strategies because of their strategic importance.

44. Renewable energy innovation systems must be seen within country and regional contexts, and, therefore, their deployment depends on various contextual factors. These include geographical and environmental conditions, macroeconomic conditions, socioeconomic and development priorities, cultural and institutional conditions, and policy and regulatory frameworks. Accordingly, countries have largely varying shares of renewables in their energy mix. For example, the share of renewable energy from total primary energy supply is 22 per cent in Colombia, mostly from hydropower, which is an important renewable energy source for electricity in Latin America. In Ethiopia, the share is almost 93 per cent, mostly from biomass. The share of renewables is 36 per cent in the Philippines, from a combination of geothermal energy, solar energy, wind energy and biomass.[34]

[34] IEA, 2017b.

45. Policymakers should balance aims and priorities for renewable energy deployment. Expansion of renewables can contribute to local or national goals, such as invigorating industrial, manufacturing and commercial sectors associated with the production and deployment of renewables, creating jobs as a result. Expanding renewable energy can also help increase income-generating opportunities for communities whose access to energy has been limited or intermittent. It can be an important contributor to gender equality by reducing time spent by women and girls gathering fuel, by increasing access to education, or by improving health through the reduction of indoor pollution. Furthermore, renewable energy can play a role in improving the productivity of agriculture, for example by enabling pumped irrigation.

46. As such, there is not one optimal pathway for the deployment of renewables, but rather a range of possible pathways. Thus, a pathway for such deployment is not a one-size-fits-all exercise but is dependent on a clear understanding of contextual factors and priorities.

B. Policy mixes are necessary to support renewable energy deployment

47. Science, technology and innovation policies should take an innovation-system approach that includes national, regional and sectoral innovation systems to support renewable energy. The systemic nature of renewables innovation requires the creation of a clear market demand for renewables and a mix of supporting policies to stimulate research and development, build local skills, coordinate players and infrastructure, align regulations and incentives, and mobilize funding.

48. Renewable energy innovation can vary in scope and scale. Some incremental innovations can lead to improvements in existing technologies, such as scaling up the size of offshore wind turbines. In the meantime, radical innovations yield new inventions and/or methods of production, such as the development of smarter, more flexible electricity systems that can help integrate variable renewable technologies in greater proportions or at a lower cost than was previously thought possible. Incremental and radical innovations are both relevant to renewable energy technologies, and policies can encourage both.

49. Applying policy mixes requires a complex system of interventions, players and processes co-evolving over a long time. Comprehensive policy mixes should include complementary types of instruments such as feed-in tariffs, international standards, demand-side measures such as public procurement, and incentives such as mission innovation programmes and bottom-up funding mechanisms, depending on country-specific challenges, priorities and different levels of technology maturity.

50. It is important to build capabilities in order to increase awareness of renewable energy technologies and to develop skills to install and maintain them. In rural energy applications, the effectiveness of training and capacity-building can be enhanced by considering social and economic factors, including gender issues. Recent research by UNCTAD underscores the importance of building local innovative capabilities, including the ability to develop and design technologies that are adapted to local needs.[35] Science, technology and innovation, and policy measures that can support local innovative capabilities may include supporting universities and research centres that focus on renewable energy technologies or providing incentives for firms for research, development and demonstration.

51. Furthermore, to maximize the effectiveness of policy mixes, appropriate policy processes and governance mechanisms are needed. These include coordination, coherence, policy learning and collaboration.

[35] E/CN.16/2010/4.

C. International and regional cooperation have a key role to play

52. Because of the international nature of renewable energy supply chains, international cooperation has an essential role to play in increasing the deployment of renewables. International cooperation can bring together different players of a supply chain or help them benefit from shared natural resources and shared infrastructure. As well as forming markets to which private players can respond in a competitive environment, Governments should be aware of where their role as a broker can improve the functioning of supply chains or enable an efficient accessing of naturally shared assets – be they natural, infrastructure or knowledge assets.

53. Interregional cooperation is especially important in mitigating different renewable energy potential due to geographical differences between neighbouring countries. Some regions have a particularly high potential for renewables, that if harnessed, could exceed the demands of the country in which they are located. Furthermore, offsetting diurnal and seasonal timing of renewable outputs of different regions can mean that the renewable outputs of such regions could effectively complement each other, if they were linked up into an integrated cross-national network. There are several initiatives and plans in this area, for example, the Nordic Grid Development Plan, which is considering new interregional transmission lines that could deliver energy surplus in one region to consumption centres.[36] Another example is the Africa Clean Energy Corridor initiative by the International Renewable Energy Agency that aims to accelerate the development of renewable energy, including cross-border trade of renewable power in the power pools of eastern and southern Africa.[37]

54. Cooperation may also include technology transfer.[38] China, for example, is facilitating wind farm development in Argentina and Pakistan,[39] while India is supporting the transfer of renewable energy technology and skills in Mozambique (box 6). The main challenge is to design policies and cooperation mechanisms that facilitate technology transfer between firms, especially in countries with emerging renewables sectors. However, technology transfer should not replace, but rather complement, domestic capacity-building efforts.[40]

55. As shown in box 6, international cooperation, including North–South and South–South cooperation, can extend to many areas: policy learning and capacity-building, technology development, improvement of the interconnection of grid infrastructures across borders, development of manufacturing capacity or contribution through funding. One notable example of the latter is a solar photovoltaic energy plant in Cobija, Plurinational State of Bolivia, that was financed almost half-half by the Bolivian National Electricity Company and Denmark.[41] The plant generates enough solar power to cover approximately half of the energy demand of Cobija during daytime hours, saves an important amount of diesel and reduces emissions.

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[36] Statnet, Fingrid, Energinet and Svenska Kraftnat, 2017, Nordic Grid Development Plan 2017, available at http://www.statnett.no/Global/Dokumenter/Nyheter%20-%20vedlegg/Nyheter%202017/Nordic%20Grid%20Deleopment%20Plan%202017.pdf (accessed 6 March 2018).

[37] Southern African Development Community, 2016, *Renewable Energy and Energy Efficiency Strategy and Action Plan: REESAP 2016–2030* (Gaborone).

[38] DG Ockwell J Watson, G MacKerron, P Pal and F Yamin, 2008, Key policy considerations for facilitating low carbon technology transfer to developing countries, *Energy Policy*, 36(11): 4104–4115.

[39] J Gosens and Y Lu, 2013, From lagging to leading? Technological innovation systems in emerging economies and the case of Chinese wind power, *Energy Policy*, 60(C):234–250.

[40] E/CN.16/2010/4.

[41] Contribution from the Government of the Plurinational State of Bolivia, available at http://unctad.org/meetings/en/Contribution/CSTD_2018_IPanel_T1_RenewableEnergy_con01_Bolivia_es.pdf (accessed 7 March 2018).

Box 6

International science, technology and innovation cooperation in renewable energy: Case studies

The Southern African Solar Thermal Training and Demonstration Initiative, or SOLTRAIN, started in 2009 with funding from the Austrian Development Agency and the Fund for International Development of the Organization of the Petroleum Exporting Countries. Since 2009, it has raised awareness and built competencies in Lesotho, Namibia, Mozambique, South Africa and Zimbabwe. During its first two phases (2009–2016), 187 small- to large-scale solar heating systems were installed, and 2,150 people trained. In the third phase, particular emphasis will be placed on demonstration projects in organizations that support women and other marginalized groups.

A solar panel factory has been set up in Mozambique with joint investment by the Governments of Mozambique and India. Mozambican technicians are being trained, including in India. The factory currently employs 33 people. Though this is a small-scale operation, it offers an interesting example of how technology and skills transfer can benefit countries by producing and deploying renewables quickly. Despite the lack of research and development background in the country, the example also illustrates how new skills and employment in the manufacturing stage of the supply chain can be developed.

Mission Innovation is a global initiative of 22 countries and the European Union that aims to accelerate global clean energy innovation in order to make clean energy widely affordable. There are seven priority innovation challenges that focus on collaborative research, development and demonstration. Several of these challenges focus on renewable energy or related innovations, including smart grids, off-grid electricity access, sustainable biofuels, new technologies to convert sunlight into energy and clean energy materials.

The Global Alliance for Clean Cookstoves is a public–private partnership that has an instrumental role in supporting the research, design and rolling out of programmes for improved cookstoves, including cookstoves using biofuel and solar energy. It emphasizes the need to develop markets by raising consumer awareness and ensuring availability and affordability. The organization brings together more than 1,600 partners worldwide, representing the private sector, Governments, non-governmental organizations, philanthropists and donors, and academia.

Sources: Contributions from the Governments of Austria, Canada and the United Kingdom, available at http://unctad.org/en/pages/MeetingDetails.aspx?meetingId=1562 (accessed 7 March 2018); Global Alliance for Clean Cookstoves, 2016, Clean Cooking: Key to Achieving Global Development and Climate Goals; Southern African Development Community, 2016.

56. International organizations and bodies such as the Commission on Science and Technology for Development can play an important role in supporting these forms of cooperation. They can provide a platform whereby countries can share lessons and best practices in the deployment of renewable energy. Moreover, they can facilitate the identification of mechanisms for improving renewable energy capabilities in developing countries. These include capabilities to develop and implement supportive policy mixes; the development of flexible plans and regulations for the energy sector that incorporate incentives for renewable energy; and measures to improve capabilities to absorb, maintain and adapt renewable energy technologies to the local context.

IV. Suggestions for consideration by Member States and the Commission on Science and Technology for Development at its twenty-first session

57. The achievement of the Sustainable Development Goals is highly dependent on increasing access to clean energy services. Increasing renewable energy deployment has a substantial implication on income generation and other development outcomes such as gender equality, health and climate change. As shown in this report, countries have different renewable energy pathways, depending on local contexts, including geographical patterns, cultural and institutional conditions, and policy and regulatory frameworks. Owing to their strategic importance for sustainable development, renewable energy policies should be incorporated in national development strategies. Furthermore, the report finds that policy mixes and a systematic approach to innovation are necessary to increase the share of renewable energy in the global energy mix. This would include measures targeting both the demand for and supply of renewables, as well as a mix of supporting policies to stimulate research and development, build skills locally, ensure affordability and create a supporting regulatory environment. Finally, international cooperation, including North–South and South–South cooperation, has a major role to play in increasing substantially the share of renewable energy in the global energy mix by 2030. International cooperation can facilitate not only knowledge sharing, policy learning, capacity-building, and technology development, but it can also contribute significantly to developing interconnected grid infrastructures.

58. Member States may wish to consider the following suggestions:

(a) Increase national support for research and development activities in renewable energy technologies and enabling technologies, and bring together government, academia, the private sector and civil society to take part in these activities, from basic research to implementation;

(b) Adopt policy mixes that allow for flexibility to support renewable energy innovation and deployment, and improve policy coordination and policy coherence with sectoral policies such as science, technology and innovation policies;

(c) Ensure the coherence of renewable energy policies with a country's broader national development agenda;

(d) Enable the contribution of grid and off-grid approaches by creating a supporting regulatory environment and tariff structure;

(e) Consider policies on renewable energy technologies to increase income-generation opportunities and contribute not only to household use, but also to the industrial, commercial and agricultural sectors;

(f) Support new business and financing models to ensure the affordability of renewable energy technologies by spreading upfront costs;

(g) Recognize and consider the social and cultural contexts of local communities, especially women, and support innovation, scaling and deployment of technologies in household-related energy services;

(h) Promote North–South, South–South and triangular partnerships on renewable energy technologies and investigate collaborative research and development mechanisms that might be effective in facilitating technology transfer;

(i) Build domestic innovative capabilities, including skills for installing, maintaining and repairing renewable energy technologies, and engage with local communities, including women, in training and maintenance of these systems.

59. The international community may wish to consider the following suggestions:

(a) Facilitate international and regional joint research activities on renewable energy, including in forecasting trends, and apply holistic approaches to examine the relationship between water, food, energy and the environment;

(b) Encourage international science, technology and innovation collaboration in renewable energy;

(c) Improve the interconnection of grid infrastructures for renewables across borders.

60. The Commission is encouraged to take the following steps:

(a) Support multi-stakeholder collaboration in policy learning, capacity-building and technology development;

(b) Improve coordination among stakeholders and enable partnerships in renewable energy that harness the specific expertise and interest of stakeholders;

(c) Encourage the sharing of lessons between countries and regions, while recognizing that policies and policy mixes cannot be simply transplanted from one context to another;

(d) Identify mechanisms for improving capabilities in developing countries for renewable energy, including capabilities to develop policies, flexible plans and regulations, and measures to improve capabilities to absorb, maintain and adapt renewable energy technologies to the local context.

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Building digital competencies to benefit from existing and emerging technologies, with a special focus on gender and youth dimensions

Report of the Secretary General

Executive summary

This report identifies the digital skills and competencies needed to exploit the development potential of existing and emerging digital technologies. It also considers how technological advances in information and communications technologies (ICTs) can help build digital skills. The report discusses the conditions and policies needed in countries, particularly in developing countries, to build digital competencies and prepare them for the current wave of technological changes. The report concludes by putting forward for consideration of Member States and the international community a set of recommendations on how to enhance digital competencies and skills.

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Introduction

1. At its twentieth session, held in Geneva, Switzerland in May 2017, the Commission on Science and Technology for Development selected as one of its two priority themes for the 2017–2018 intersessional period, "Building digital competencies to benefit from existing and emerging technologies, with a special focus on gender and youth dimensions".

2. To contribute to a better understanding of this priority theme and to assist the Commission in its deliberations at its twenty-first session, the secretariat of the Commission convened a panel meeting in Geneva from 6 to 8 November 2017. This report is based on the issues paper prepared by the Commission secretariat,[1] the findings of the panel, country case studies contributed by Commission members, relevant literature and other sources.

I. Technological change and its impact

3. Technological changes observed in recent years, particularly driven by the rapid development of ICTs, offers the potential to transform economies and improve the living standards of many people. Furthermore, it has a strong potential to disrupt productive sectors and markets, including through technological convergence and recombination.

4. Recent advances in ICTs, characterized by a reliance on digital data storage and analytics, fast-growing capabilities at a declining cost and increasing ease of use, have led to an increasing democratization of technologies. Examples of these technologies include the Internet of Things, big data, artificial intelligence, robotics, automation, three-dimensional printing, biotechnology, nano- and microsatellites, neurotechnology, synthetic biology, nanomaterials, advance energy storage technologies and blockchain.[2] The applications of these technologies offer new opportunities for economic prosperity, social inclusion, and environmental sustainability, including through technological convergence and recombination. Furthermore, the cross-cutting application of many emerging technologies, especially those digitally enabled, can also contribute to sustainable development.[3] Examples of these applications include sensor devices for improving agricultural productivity, microinsurance for farmers distributed through mobile devices, mapping data for the control of epidemic outbreaks and smart water-management systems.[4]

5. The implications of current technological advances for labour markets and jobs have been the subject of much debate, which has largely focused on the impact of digital platforms and automation. It has been observed that while digital platforms are creating new types of occupations and generating entrepreneurial opportunities – especially for women – they can also create greater pressure on pay and working conditions, owing to work fragmentation and the provision of remote services.[5] As regards automation, the increased automation of tasks can release workers from dangerous, predictable and routine tasks so they can pursue safer, more creative and interesting work tasks, as well as leisure activities. However, it can also reduce the need for workers and potentially even whole industries, since it raises productivity and can increase the scale of operations at marginal cost.[6] The net impact of new technologies and their consequences on labour

[1] The issues paper, presentations and contributions to the intersessional panel cited in this report are available at http://unctad.org/en/pages/MeetingDetails.aspx?meetingid=1562 (accessed 27 February 2018).

[2] Organization for Economic Cooperation and Development (OECD), 2016, *OECD Science, Technology and Innovation Outlook 2016* (OECD Publishing, Paris); E/CN.16/2016/3.

[3] A/72/257.

[4] E/CN.16/2016/3.

[5] J Drahokoupil and B Fabo, 2016, The platform economy and the disruption of the employment relationship, European Trade Union Institute Policy Brief No. 5.

[6] E/CN.16/2016/3.

markets and jobs remains uncertain, including on the type of jobs and sectors that will remain or will be created.

6. Technological change can affect women and men differently.[7] ICT services provide relatively well-remunerated employment for women, but the share of women in ICT specialist occupations remains very low, especially in developing countries.[8] A recent survey among 13 major developed and emerging economies revealed that female employment is concentrated in low-growth or declining occupations, such as sales, business and clerical work. Women are also less represented in sectors in which automation is expected to displace jobs such as manufacturing and construction. Further, there are few women in the science, technology, engineering and mathematics (STEM) job families and may therefore not be able to take advantage of the increased demand for workers with skills in these areas.[9]

7. Taken together, rapid technological change offers potentially transforming development opportunities for countries but also creates significant concerns that policymakers need to address to ensure technologies are leveraged for sustainable and inclusive development. Development gains offered by new and emerging technologies are not automatic. While new technologies create new jobs and development opportunities, they also increase the demand for digital skills and competencies.[10] This underlines the importance of addressing the gaps that exist in terms of capabilities across and between countries, sectors and segments of the society, so that societies can adapt and benefit from technological changes.

II. Digital skills and competencies

8. Estimates indicate that 85–90 per cent of future jobs will require ICT skills by 2020.[11] More than a third of the labour force in OECD countries, however, is reported to have an extremely low capacity to use digital technologies productively, while 56 per cent of the population has no ICT skills.[12] Also, women were more likely than men to lack digital skills. The widening gap between the knowledge, skills and abilities of young people entering the workforce and the knowledge, skills, and abilities that employers are seeking has been identified as an important deterrent to growth.[13] Moreover, developing countries are witnessing an increase of young people in the labour market. About half a billion young Chinese and Indian people will join the workforce in the coming decades. In Africa, it is expected that about 11 million young Africans will join the labour market every year for the next decade.[14] This stresses the need for policymakers and educators to adapt educational curricula to changing labour markets demands.

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[7] OECD, 2017, Going digital: The future of work for women, Policy Brief on The Future of Work.

[8] UNCTAD, 2017, *Information Economy Report 2017: Digitalization, Trade and Development* (United Nations publication, Sales No. E.17.II.D.8, New York and Geneva).

[9] E/CN.16/2016/3.

[10] Further, inequality in the skills that allow people to use technologies is one factor that could potentially exacerbate the digital divide. In addition to access to the Internet, ICT user sophistication and digital skills for Internet use have also been identified as determinants of the digital divide. See E Hargittai, 2003, How wide a Web? Inequalities in accessing information online; E Hargittai and A Hinnant, 2008, Digital inequality differences in young adults' use of the Internet, *Communication Research*, 35(5):602–621.

[11] https://ec.europa.eu/jrc/en/news/job-market-fails-unleash-ict-potential-9692 (accessed 27 February 2018).

[12] Broadband Commission for Sustainable Development, 2017, Working Group on Education: Digital Skills for Life and Work.

[13] The Economist Corporate Network, 2016, *Shaping the Future of Work: Technology's Role in Employment* (Dubai).

[14] https://openknowledge.worldbank.org/bitstream/handle/10986/25010/Will0the0digit00realizing0job0gains.pdf?sequence=1&isAllowed=y (accessed 28 February 2018).

9. At the same time, the effects of ICTs are not limited to jobs but also to social and civic participation in societies. Having the necessary digital competencies enhances people's quality of life and the effectiveness of their work. Therefore, digital competencies and skills are essential to ensure effective participation in the current and future world as well as to benefit from existing and emerging technologies.

A. Digital skills and competencies for the twenty-first century

10. In general, digital competence encompasses the knowledge and skills required for an individual to be able to use ICT to accomplish goals in his or her personal or professional life. Digital competencies should be perceived as not only concerned with technical skills, but more focused on cognitive and social and emotional aspects of working and living in a digital environment.[15] The notion is a complex one, and beyond digital literacy, implies the ability to understand media, to search for information and be critical about what is retrieved, and to be able to communicate with others using a variety of digital tools and applications. Digital competence is a multifaceted moving target, which is constantly evolving as new technologies appear.[16]

11. Different types of digital competencies are needed to adapt to the changing technological landscape. Six major drivers are among those relevant for the work skills and digital competences of the future: increasing globalization, extreme longevity, workplace automation, fast diffusion of sensors and data processing power, ICT-enabled communication tools and media, and the unprecedented reorganization of work driven by new technologies and social media, which are massively increasing collaboration opportunities.[17] Several organizations and initiatives have carried through efforts to identify and categorize the digital skills and competencies needed for the future. Table 1 presents examples of selected categorizations of such skills and competencies.

Table 1
Different categorizations of digital skills

Job-ready digital skills for decent jobs (International Labour Organization and International Telecommunication Union (ITU))	Advanced digital skills (coding and other algorithmic knowledge) Basic digital skills (related to the use of technologies) Soft skills (such as communication and leadership) Digital entrepreneurship (online market research and using financial platforms)
Work-related skills (World Economic Forum)	Abilities (cognitive and physical) Basic skills (content and processing skills) Cross-functional skills (social systems, complex problem solving, resource management and technical skills)
Future of work (OECD)	Technical and professional skills (specific and often industry-specific skills such as installation and operation of robots) Generic ICT skills (skills needed to understand, use and adopt technologies; life-learning ability to adapt to technology changes) Complementary ICT soft skills (creativity, communication skills, critical and logical thinking, teamwork, digital entrepreneurship)

Source: ITU, 2018, ILO-ITU Digital Skills for Decent Jobs for Youth Campaign to train 5 million youth with job-ready digital skills; OECD, 2016, Skills for a digital world. Policy Brief on the Future of Work. World Economic Forum, 2016, *The Future of Jobs: Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution* (Geneva).

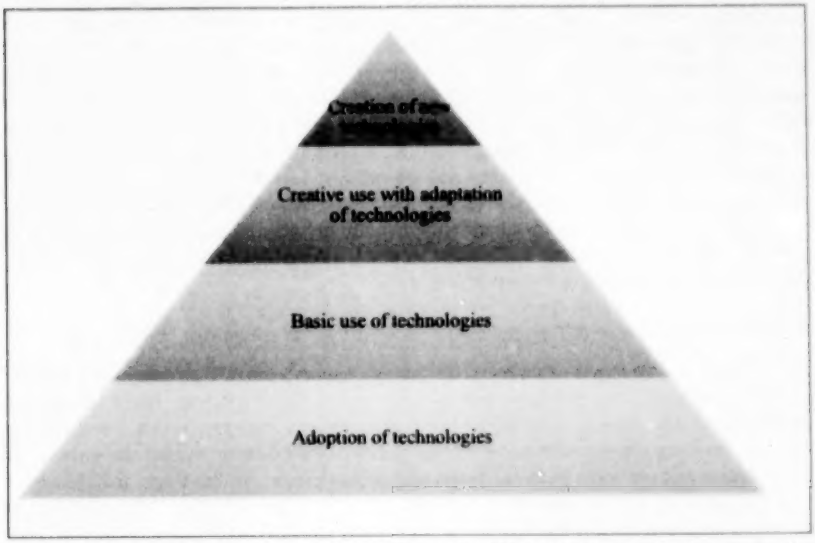
[15] Y Eshet-Alkai, 2004, Digital literacy: A conceptual framework for survival skills in the digital era. *Journal of Educational Multimedia and Hypermedia*, 13(1):93–106.

[16] A Ferrari, 2013, *DIGCOMP: a Framework for Developing and Understanding Digital Competence in Europe* (European Union, Luxembourg).

[17] Institute for the Future, 2011, Future Work Skills 2020.

12. Four different levels of digital skills are needed during the process of adoption, use and domestication of technologies: those required to adopt technologies, those needed in the basic use of technologies, those necessary for the creative use and adaptation of technologies, and those essential for the creation of new technologies. These categories can be further grouped into two categories: skill sets for all and skill sets for ICT professionals (see figure and table 2).

Pyramid of digital skills



Source: P DiMaggio, E Hargittai, C Celeste and S Shafer, 2004, Digital inequality: From unequal access to differentiated use, in *Social Inequality* (Russell Sage Foundation).

Table 2
Categories and levels of digital skills

Category	*Levels*	*Skills*
Digital skills for all	Adoption	Basic education and literacy Familiarity with technology devices and services
	Basic or generic use	Basic understanding of technologies, software and applications; Knowledge of digital rights, privacy, security and permanence of data[a] Ability to make use of information and data, ranging from basic issues of data storage, management, and organization to construct calculations and answer questions[a] Ability to using digital technologies to collaborate, communicate and create[a]
Digital skills for ICT professionals	Creative use and adaptations	Basic computing skills Familiarity with basic algorithms
	Creation of new technologies	Sophisticated programming skills; knowledge of complex algorithms

Source: Di Maggio et al., 2004.

[a] Broadband Commission for Sustainable Development, 2017.

Digital competencies for all: Adoption and basic use of technologies

13. The most fundamental skill sets for individuals and companies in the digital era are capabilities to adopt new technologies. In this context, "digital literacy for all" is a basic requirement to enable every citizen to participate fully in the digital society.[18] For individuals, this involves basic education and literacy, as well as familiarity with technology devices; for companies, this contains knowledge about ICT installations in the existing business system. After individuals and companies have basic access to technologies, the next levels of digital skills are those that facilitate the direct use of technologies, which include a basic understanding of emerging technologies and technology applications, and knowledge about digital privacy and security. This type of knowledge enables users to actively extract the information they need from the Internet, instead of passively being receivers and targets of online advertisements.[19] Knowing how technology works can help users improve the efficiency of usage and optimize the outcome of technology usage. With increasing numbers of software and applications being used to accomplish everyday communicational and informational tasks, basic knowledge of ICTs is now essential for citizens to solve everyday problems, as well as to engage in community activities. Some non-ICT professionals may increasingly need to develop stronger skills to perform their duties. Some of these skills include proficiency in programming languages, data analysis and processing and modelling skills.[20]

Digital competencies for ICT professionals: Adaptation and creation of technologies

14. There are two types of digital skills that are required for ICT professionals: skills to adapt and creatively use available technologies, and skills to innovate based on adapted technologies. The former is required for individuals or companies that have already acquired basic computing skills or have hired technical staff that can modify the software or technologies to meet individualized needs and requirements. At this stage, individuals or ICT departments within companies understand basic algorithms, and can use online resources to create new functions or develop more suitable applications when needed. Although a degree in ICT-related subjects such as computer science is not required at this level, training in statistics, programming languages and big data analytics are necessary. The ability to redesign or modify technologies for creative use is also the key for localizing emerging technologies in developing countries. Skills to innovate based on adapted technologies include sophisticated programming skills and knowledge of complex algorithms.

15. Many of the advanced technologies are designed to be used in contexts where infrastructure, and natural and social resources differ from those in developing economies. To maximize the benefits of new technology, countries and companies in developing countries need to have the digital skills to introduce modifications to new technologies.[21] The creation of new technology is the final and the most advanced level of digital skills. Individuals who have sophisticated programming skills or companies that have a good knowledge of complex algorithms such as machine learning, will have the capabilities to contribute to the creation of more advanced technologies or the development of technology innovations.

16. While education and training programmes that focus on digital skills for all – including training in the adoption and use of technology – should be inclusive and accessible to everyone, needs for other types of digital competencies vary across sectors, countries and levels of industrial development. In countries where technology development remains in its early stages, basic technical skills and generic skills are the most required. Countries where the manufacturing sector dominates economic growth will require talents, experts and a workforce with specialized skills in industrial robotics, automation and the

[18] Broadband Commission for Sustainable Development, 2017.

[19] WR Neuman, 2016, *The Digital Difference: Media Technology and the Theory of Communication Effects* (Harvard University Press, London).

[20] Broadband Commission for Sustainable Development, 2017.

[21] Z Huang and P Palvia, 2001, ERP implementation issues in advanced and developing countries, *Business Process Management Journal*, 7(3):276-284.

Internet of Things. Skills that enable workers to work with new technologies are increasing; as a result, certain complementary soft skills are also needed in digitally transformed manufacturing environments.[22] In countries where the services industries, such as tourism, and financial and health-care services, are prosperous and growing, there is a higher demand for sophisticated and specialized digital competencies.

B. Complementary skills

17. Digital skills are not enough to adapt to the changing labour markets demands. There is an increasing demand to strengthen those unique human skills that cannot be easily replaced by machines, computers and robots. In addition to digital competencies, building and strengthening complementary skills such as complex problem solving, critical thinking, and creativity, are essential to create the flexibility required for the current and future demands for the workforce.

18. Research shows that occupations such as engineering and science are less susceptible to digitalization and computerization because these professions involve a higher degree of creativity and innovation compared with other jobs.[23] Occupations that involve sophisticated communication skills are also in a more secure position in the digital era. For example, natural language processing algorithms can detect emotions underlying text, but are often inaccurate in comprehending sarcasm, humour or irony. When equipping a future workforce with complementary soft skills, it is also important to develop critical and logical thinking abilities, which are vital when preparing young people with abilities in problem solving and decision-making. With the increase of the platform economy, soft skills for digital entrepreneurship are important for individuals to benefit from the digital economy.[24] Many countries have highlighted the importance of providing related training on e-business. For instance, Turkey aims to increase the percentage of individuals with entrepreneurship training from 6.3 per cent in 2012 to 15 per cent in 2018.[25] A non-exhaustive list of complementary skills is presented in table 3.

[22] National Academies of Science, Engineering, and Medicine, 2017, *Information Technology and the United States [of America] Workforce: Where Are We and Where Do We Go from Here?* (National Academies Press, Washington, D.C.).

[23] CB Frey and MA Osborne, 2017, The future of employment: How susceptible are jobs to computerization? *Technological Forecasting and Social Change*, 114(C):254-280.

[24] Contribution from United Nations Major Group for Children and Youth. In addition to training, other factors also influence entrepreneurship initiatives, particularly of youth. These include risk management, high overhead costs and difficulty in gaining financial and legal legitimacy.

[25] Contribution from the Government of Turkey, available at http://unctad.org/meetings/en/Contribution/CSTD_2018_IPanel_T2_DigitalComp_con23_Turkey_en.pdf (accessed 27 February 2018).

Table 3
Complementary soft skills for the future workforce

Type of soft skills	*Description*
Sense making	Ability to determine the deeper meaning or significance of what is being expressed
Social intelligence	Ability to connect with others in a deep and direct way, to sense and stimulate reactions and desired interactions
Computational thinking	Ability to translate vast amounts of data into abstract concepts and to understand data-based reasoning
Novel and adaptive thinking	Proficiency at thinking and coming up with solutions and responses beyond that which is rote or rule based
Cross-cultural competency	Ability to operate in different cultural settings
New media literacy	Ability to critically assess and develop content that uses new media forms, and to leverage these media for persuasive communication
Transdisciplinarity	Literacy in the ability to understand concepts across multiple disciplines
Design mindset	Ability to represent and develop tasks and work processes for desired outcomes
Cognitive load management	Ability to discriminate and filter information for importance, and to understand how to maximize cognitive functioning using a variety of tools and techniques
Virtual collaboration	Ability to work productively, drive engagement, and demonstrate presence as a member of a virtual team

Source: Institute for the Future, 2011.

III. Emerging and existing technologies for education

19. Traditional teaching curricula and training programmes can contribute to the enhancement of digital skills; in addition, new and emerging technologies can also help build digital competencies. In particular, digital technologies enable interactions between educators and students, provide multimedia interfaces that facilitate learning and increase flexibility in the delivery of training. Recent literature has identified massive open online courses, open access to scientific literature and educational resources, and technology-mediated teaching and learning as some of the existing and emerging technologies that can potentially contribute to building digital skills and competencies.[26]

A. Massive open online courses

20. Massive open online courses are online courses that allow for open access and participation through the World Wide Web and that could contribute to e-learning. They offer various features in addition to online video lectures, including online social sharing and interactive learning methods, community teaching assistants that moderate discussion forums and tracking of the activities and performance of students. Potentially, these courses could deliver mass education at a low cost and help achieve Sustainable Development Goal 4 ("ensure inclusive and equitable quality education and promote lifelong learning opportunities for all"). There are a variety of factors, however, that may

[26] For instance, the Commission on Science and Technology for Development examined open access, virtual libraries and the potential of massive open online courses in education delivery during its fifteenth and nineteenth annual sessions. See www.unctad.org/cstd (accessed 27 February 2018).

reduce the potential access and use of these courses, including issues related to infrastructure access (since these courses require users to have access to a reliable Internet connection, including upgraded software and hardware) and to the content of the educational material (courses are generally available in English and may not consider relevant local content).[27] These issues underscore the importance of reducing the digital divide and considering local needs in the developing the courses.

B. Open access to scientific literature and educational resources

21. The creation of new technologies requires the exchange of information and knowledge worldwide. Open access databases and journals of scientific literature allow scientific knowledge to be accessed without cost. Open access publishers, such as the Public Library of Science, distribute digital copies of research articles online and provide open access for users.[28] Traditional scientific publishers are also helping make science accessible in developing countries.[29]

22. Scientists are increasingly using archiving websites to share their research with a much wider audience. For instance, the Bexar County Digital Library in San Antonio, Texas, United States, offers digital content, access to online databases and educational resources to increase literacy and digital literacy among lower socioeconomic communities.[30] Other related efforts include the development of educational resources openly available for use by educators and students, without an accompanying need to pay royalties or licence fees.[31] For instance, Latvia has a natural sciences and mathematics project that has allowed the production of supporting materials for teachers in biology, physics, mathematics and chemistry (International Standard Classification of Education level 2), which are available on the Internet.

C. Technology-mediated teaching and learning

23. Existing and emerging technologies such as the Internet can help build digital competencies by making learning materials accessible to teachers and students. For instance, in Bulgaria the Daskal.eu initiative uses an online platform to connect students and teachers by providing technological tools for setting up virtual classrooms and real-time video streams. Among the users of this type of platform are freelance teachers, students in need of extracurricular classes and, in some cases, whole schools conducting some of their classes from a distance.[32] In South Africa, the Digital Doorway programme provides women in remote rural areas with ICT access to obtain agricultural information.[33]

24. In remote areas, media centres could serve as educational institutes that, in addition to providing education, can also track and assess the performance of students. For example, a media centre in Brazil helps children in remote communities to continue schooling. The centre provides technologies and complementary human interaction. While a bidirectional camera enables teachers to interact with students remotely, a tutoring teacher supports the students' learning by helping manage classes and administrative

[27] B Moser-Mercer, 2014, Massive open online courses in fragile contexts, Proceedings of the European Massive Open Online Courses Stakeholders Summit 2014, Lausanne, Switzerland, 10–12 February.

[28] https://www.plos.org/open-access/ (accessed 27 February 2018).

[29] http://www.pnas.org/site/aboutpnas/developingcountries.xhtml (accessed 27 February 2018).

[30] Contribution from the Government of the United States, available at http://unctad.org/meetings/en/Contribution/CSTD_2018_IPanel_T2_DigitalComp_con26_US_en.pdf (accessed 27 February 2018).

[31] For more information on open educational resources, see http://unesdoc.unesco.org/images/0021/002158/215804e.pdf (accessed 27 February 2018).

[32] Contribution from the Government of Bulgaria, available at http://unctad.org/meetings/en/Contribution/CSTD_2018_IPanel_T2_DigitalComp_con15_Bulgaria_en.pdf (accessed 27 February 2018).

[33] Contribution from the Government of South Africa, available at http://unctad.org/meetings/en/Contribution/CSTD_2018_IPanel_T2_DigitalComp_con22_SouthAfrica_en.pdf (accessed 27 February 2018).

issues.[34] Therefore, students benefit from technological advances because remote learning becomes a more interactive and engaging experience.

25. New technologies, such as artificial intelligence and big data analytics, can also help teachers make assessments or provide feedback by, among others, producing intelligent scoring, interpreting of individual profiles and providing advice to learners and teachers by inference procedures.[35] Assessment of performance is therefore done in real time; in addition, it is flexible and embedded in the teaching process.

26. Table 4 describes some examples of potential uses of big data for education. General Assembly and Singularity University, both located in the United States, are two examples of educational organizations created to cater for the growing demand for digital skills and lifelong learning, and to interact with and develop technologies developing at exponential rates.[36]

Table 4
Potential uses of big data for education

Beneficiaries	*Potential contribution of big data*
Students in schools, colleges and university	Provide feedback on their measured progress and recommendations on what to do to improve
Teachers	Review and evaluate courses and track student's engagement and achievement
School and university leaders	Review and evaluate intuitional and staff performance at the same time
Policymakers	Help learn about institutional and system performance and generate insights for future policy intervention

Source: B Williamson, 2017, *Big Data in Education: The Digital Future of Learning, Policy and Practice* (Sage, London).

27. To benefit from technologies in education, it is necessary to have access to reliable and updated ICT infrastructure, ensure the continuous training of teachers and consider the long-term sustainability of the programmes. Also, resources should be adapted and restructured to fit local contexts for youth in low-and-middle-income countries, especially in rural regions.[37]

28. Further, digital learning technologies such as massive open online course do not guarantee improved educational outcomes, and only through experimentation, monitoring and evaluation can its impact be assessed. Also, when analysing the sustainability and scaling up of e-learning projects, the educational goals and pedagogical approaches appropriate for a specific country or region should be considered.

IV. Initiatives to help build competencies

29. Building the competencies and skills required to understand, adopt, use and create new technologies, particularly ICTs, is central for individuals to participate effectively in and benefit from technologies. Digital competencies, soft skills and access to new technologies, however, are not equally distributed among regions and groups. Therefore, some countries do not have the capacities to leverage technology for development.

[34] https://www.brookings.edu/research/millions-learning-scaling-up-quality-education-in-developing-countries/ (accessed 27 February 2018).

[35] C Redecker and O Johannessen, 2013, Changing assessment: Towards a new assessment paradigm using ICT, *European Journal of Education*, 48(1):79–96.

[36] https://www.economist.com/news/special-report/21714169-technological-change-demands-stronger-and-more-continuous-connections-between-education (accessed 27 February 2018).

[37] Contribution from United Nations Major Group for Children and Youth.

The rapid pace of technological development requires constant adaptation and flexibility in the types of competencies required. This stresses the need for developing and developed countries alike to put competence building at the forefront of their development strategies. This section describes three areas in which concerted efforts are required to enable and promote the creation and strengthening of digital competencies and soft skills.

A. Incorporating digital competencies in the education system

30. Education is central to preparing the workforce and society to benefit from exponential technologies. Also, training is central to people's ability to leverage technologies for innovation and sustainable development. Education policy needs to accommodate new requirements for digital skills training schemes, making acquisition of digital competencies part of the education goals. Furthermore, the changes in the types of skills and competencies needed to take advantage of current and emerging technologies have implications for formal education systems, as well as for private and public skills development strategies. This will require changes to education and training systems, as well as individual attitudes, and it may involve crafting appropriate curricula now for skills and jobs that will be required in the future.[38] Training in digital competencies, including soft skills, should be incorporated at all levels in the education system (primary, secondary, tertiary) and as part of vocational training and lifelong updating and upscaling of skills for the workforce. The programmes should allow for flexibility so they can be adapted according to technological changes.[39]

Building digital competencies at schools

31. Education policies should emphasize the importance of providing digital training to primary and secondary school students, and programmes and curricula should adjust and allow for flexibility so they can continously adapt to the changing technological landscape. It is important to consider teaching a broad range of skills, from simple operations of desktop computers and text processing tools, to more rigorous courses that teach students to understand fundamental computing languages, and establish their algorithmic thinking skills. Education programmes should consider mobile devices not only as information seeking tools but also as tools for productivity scenarios, since users seldom use mobile phones in activities such as job seeking or online learning.[40] Furthermore, education policies should also consider the continuous training of teachers. For instance, the teacher-training strategy of the Plurinational State of Bolivia provided ICT training to more than 200,000 teachers between 2010 and 2015.[41]

32. Encouraging the participation of girls in the study and professions of science, technology, engineering and mathematics in both developed and developing countries can help build intermediate- and advanced-level digital skills.[42] In higher education, girls represent 35 per cent of all students enrolled in such areas. Many reasons explain this bias, including societal and parental attitudes towards the abilities of boys and girls, access to education and bias in teaching material and curricula, as well as perceptions that girls are less able to "do" science.[43] Moreover, women who enter such professions leave in disproportionate numbers compared with men.[44] The integration of the broad field of the arts into science, technology, engineering and mathematics could potentially help increase women's engagement in these areas.[45]

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[38] UNCTAD, 2017.

[39] The Economist Corporate Network, 2016.

[40] J Donner, 2015, *After Access* (MIT Press, Cambridge, Massachusetts, United States).

[41] Contribution from the Government of the Plurinational State of Bolivia, available at http://unctad.org/meetings/en/Contribution/CSTD_2018_IPanel_T2_DigitalComp_con14_Bolivia_es.pdf (accessed 27 February 2018).

[42] Broadband Commission for Sustainable Development, 2017.

[43] UNCTAD, 2011, *Applying a Gender Lens to Science, Technology and Innovation*, UNCTAD Current Studies on Science, Technology and Innovation, No. 5 (United Nations publication, Geneva).

[44] Broadband Commission for Sustainable Development, 2017.

[45] https://stemdiversity.wisc.edu/featured/why-art-is-the-key-to-closing-the-stem-gender-gap/ (accessed 27 February 2018).

Digital competencies as part of vocational training

33. Introducing professional digital skills training, such as coding, data analysis and e-business skills, can help young people seize new opportunities offered in the future job market. For example, in the United Kingdom of Great Britain and Northern Ireland, the Ada National College for Digital Skills provides digital skills training to students, with a special focus on female students and those from lower-income backgrounds.[46] Another example is the Industry 4.0 project in Turkey, which aims to provide young students in vocational schools with skills training and knowledge in emerging technologies, such as the Internet of Things.[47] To provide digital skills in vocational education, schools should work closely with industry to update the content of curricula and courses, since technologies advance at a rapid pace, and workers need to upskill constantly. Creating interfaces between schools and industries can help facilitate this type of collaboration.

34. In addition, it is important to support firms, community school and civil society organizations working on the provision of training of broad skills to the existing workforce and the population. This should include broad skills in digital competencies such as basic ICT skills for work and for wide social life, lifelong learning capabilities and entrepreneurship skills.

Digital competencies and lifelong learning

35. Estimations suggest that by 2030, 75 million to 375 million workers, representing 3 to 14 per cent of the global workforce, will need to switch occupational categories.[48] What becomes relevant is to think in terms of skills – and not so much in terms of jobs – and match those skills with labour market needs. Furthermore, since technologies advance at an unprecedented speed, digital skills training programmes need to constantly update to provide the most important professional skills for adult students. The term "learnability" – the desire and capability to develop in-demand skills to be employable for the long term – has recently emerged to describe the key attribute that employers demand in an environment of rapid technological change.[49]

36. Traditional community centres such as libraries could provide new training programmes for members of the community. For example, as part of the National Strategy for Lifelong Learning (2014–2020) of Bulgaria, public libraries in this country provide digital skills training for various social groups.[50] In Poland, the Office of Electronic Communications organizes coding courses to strengthen the development of creative and analytical thinking.[51] It is also necessary to fully exploit the potential of digital technologies such as social media and online training in lifelong learning and on-the-job training.

37. As digital technologies become increasingly important for both employment and everyday life, women in developing countries require basic digital literacy to either compete with male workers in the job market or manage everyday household tasks. A project called the Citizens Foundation has conducted an assessment of women's digital

[46] Contribution from the Government of the United Kingdom, available at http://unctad.org/meetings/en/Contribution/CSTD_2018_IPanel_T2_DigitalComp_con25_UK_en.pdf (accessed 27 February 2018).

[47] Contribution from the Government of Turkey, available at http://unctad.org/meetings/en/Contribution/CSTD_2018_IPanel_T2_DigitalComp_con23_Turkey_en.pdf (accessed 27 February 2018).

[48] https://www.mckinsey.com/global-themes/future-of-organizations-and-work/what-the-future-of-work-will-mean-for-jobs-skills-and-wages (accessed 27 February 2018).

[49] https://www.weforum.org/agenda/2016/08/this-little-known-skill-will-save-your-job-and-your-company/ (accessed 27 February 2018).

[50] Contribution from the Government of Bulgaria, available at http://unctad.org/meetings/en/Contribution/CSTD_2018_IPanel_T2_DigitalComp_con15_Bulgaria_en.pdf (accessed 27 February 2018).

[51] Contribution from the Government of Poland, available at http://unctad.org/meetings/en/Contribution/CSTD_2018_IPanel_T2_DigitalComp_con20_Poland_en.pdf (accessed 27 February 2018).

educational needs and developed an online platform to facilitate literacy education for women living in rural Pakistan.[52] For women in developing countries, basic Internet connectivity should be provided by the Government to meet their ICT needs. The Government of Kenya aims to provide Internet access to local communities, which will include women and persons with disabilities.[53]

38. There is no one-size-fits-all or single recipe for education and lifelong learning policy, as it is important to consider the different circumstances of the countries in terms of the level of development and industrialization, skills needs and levels of education and training capabilities.

B. Importance of an enabling environment to support skills development

39. The creation of an environment facilitates building digital competencies and contributes to leverage their potential. An enabling environment is promoted through investment in infrastructure, institution development and entrepreneurship, among others.

Investment in digital infrastructure

40. A fundamental element of the digital capacity of countries is their digital infrastructure. Only those that are connected and that have the required capabilities will be able to take advantage of the development opportunities offered by current changes in technology. Therefore, in addition to investing in capacity-building, it is essential to reduce the digital divide. This can be achieved, for example, by investing in infrastructure.

41. Estimates show that almost 4 billion people – more than half the world's population – do not have Internet access.[54] Particularly noteworthy is the gender dimension of the digital divide. Although the gap has narrowed in terms of using the Internet (currently 12 per cent), it has widened in Africa (25 per cent) and in the least developed countries, where only one out of seven women use the Internet, compared with one out of five men. Broadband connectivity in developing countries, when available, tends to be relatively slow and expensive, limiting the ability of businesses and people to use it productively. Infrastructure investment is critical to tackling the inequalities in access and leveraging benefits from existing and emerging technologies, particularly in the least developed countries, landlocked countries and small island developing States where geographical constraints, low population densities and limited resources make it more difficult for private investors to secure rapid returns on capital. In this regard, international financial institutions and development partners have an important role to play, alongside private sector businesses and Governments.

42. Moreover, there is an infrastructure gap between technology adoption at home and in the classroom. While families and individuals widely adopt ICTs, recent research suggests that schools lag behind in the adoption of new technologies: 96 per cent of students in OECD countries have computers at home, but only 72 per cent reported using ICTs at school.[55] This gap between school and home use of ICTs is wider in developing countries, where villages and local communities have shortages of public ICT facilities. To narrow the technology gap at home, it would be advisable to build information centres equipped with ICT facilities in local communities or to provide affordable mobile technologies such as tablets to low-income families. For example, a public-private partnership in the United States, ConnectHome, provides free or low-cost broadband

[52] https://en.unesco.org/news/community-engagement-and-online-literacy-empower-girls-and-women-pakistan (accessed 28 February 2018).

[53] Contribution from the Government of Kenya, available at http://unctad.org/meetings/en/Contribution/CSTD_2018_IPanel_T2_DigitalComp_con18_Kenya_en.pdf (accessed 27 February 2018).

[54] ITU, 2017, *ICT Facts and Figures 2017* (Geneva).

[55] OECD, 2015, *Students, Computers and Learning: Making the Connection* (OECD Publishing).

access, and device and digital literacy training to low-income families, aiming to narrow the digital divide at home.[56]

43. Investment in digital infrastructure includes investing in data resources and the facilities and capabilities for collecting, analysing and using big data. Efforts in this area include building national big data centres, achieving full broadband coverage in developing countries and investing in regional high-speed computing and processing facilities for big data analysis. Investment in infrastructure can also help build digital competencies. For instance, online platforms and education applications can help countries educate and train the workforce and citizens. However, to make data to work for societies, it is also necessary to build analytical capabilities in policy- and decision-making processes.

Policy and institutional development

44. To build digital competencies, it is essential to have appropriate institutions that set rules creating incentives that motivate workers, management, firms, universities and other entities to adopt and develop the necessary skills. These institutions include laws and regulations, organizations such as vocational schools and community schools that support professional training and lifelong learning, university departments and centres that conduct research and develop digital technologies and their applications, non-governmental organizations and social organizations that provide support to the wider society for digitalization, adoption and use.

45. Other efforts in areas such as taxation, financing, industry and labour market policies can also help develop an incentive structure that encourages and facilitates investment and labour participation in the digital economy. A descripiton of selected national strategies aimed at equipping countries with the resources needed to benefit from technogical advances is provided in the following box.

[56] Contribution from the Government of the United States, available at http://unctad.org/meetings/en/Contribution/CSTD_2018_IPanel_T2_DigitalComp_con26_US_en.pdf (accessed 27 February 2018).

Selected national strategies aimed at increasing digital competencies of countries

- Bulgaria. Digital Bulgaria 2020 programme: Sets forth the country's current priorities in the global process of digitalization, including bridging the digital divide, increasing digital literacy and competencies of individuals, and reducing the shortage of highly qualified workers in the high-technology sector.

- Canada. Innovation and Skills Plan: Aims to make Canada a world-leading centre for innovation, help create more well-paying jobs, and strengthen and expand the middle class. It includes equipping citizens with the tools, skills and experience they need to succeed in the workforce, now and in the future.

- Kenya. National ICT Master Plan: Road map based on the ICT theme "Strengthening the foundation for a knowledge-based economy". Considers strategies to enhanced public value, development of ICT businesses and strengthening of ICT as a driver of industry.

- Portugal. National Digital Competences Initiative e.2030 (INCoDE.2030): Brings together public and private organizations to generalize digital literacy, stimulate employability, professional training and specialization in digital technologies and applications, and ensure strong participation in international research and development networks and the production of new knowledge in digital areas.

- South Africa. Revised National Broadband Policy and Broadband Strategy: Aimed at ensuring universal access to reliable, affordable and secure broadband infrastructure and services by 2020 and stimulating sustainable uptake and usage of ICTs.

- Uganda. Digital Uganda Vision: Addresses issues related to infrastructure support, policy framework, access to ICTs, capacity development, collaboration among various agencies, common access of government services by citizens, delivery of services and participative access.

- United Kingdom. Digital Skills and Inclusion Policy: Aims to ensure that everyone who is capable of participating in the digital economy does so.

- United States. Federal Open Data: An open government data initiative that contributes to modernizing government and improving the delivery of services provided by government, industry and non-governmental organizations.

Source: Contributions from Member States of the Commission on Science and Technology for Development, available at http://unctad.org/en/pages/MeetingDetails.aspx?meetingid=1562 (accessed 27 February 2018).

C. Collaboration among stakeholders

46. The improvement of digital competencies requires extensive investment in training staff, designing curricula and providing information centres, all of which call for more in-depth international collaboration. There are several areas in which collaboration among stakeholders can contribute to the strengthening of digital competencies in countries, for instance, through public–private partnerships in delivering digital skills and building digital infrastructure, and through international collaboration among stakeholders for capacity-building and research.

Public–private partnerships

47. Public–private partnerships can support training provision, infrastructure development and building of data facilities. Technology companies are already playing important roles in some developed countries to support the training and teaching of digital skills. For example, Microsoft works with the British Government to train civil servants how to use new technologies such as cloud services.[57] Furthermore, since technology companies have advantages in software engineering and interface designing, there is also potential for collaboration that considers the provisions of equipment and software specifically designed for educational purposes. Developers of Swift, an educational application on electronic devices, design an interactive and playful interface for children to learn to code.[58] Also, collaboration among stakeholders can also contribute to sharing information on demand and supply of skills digital competencies, provide on-the-job training and internships; and introduce cutting-edge technological skills to learners. For example, Portugal established a partnership with several universities, including the Massachusetts Institute of Technology, Carnegie Mellon University and Indian Institutes of Technology, to establish networks that support the enhancement of digital competencies.[59]

International collaboration

48. International collaboration can contribute to the strengthening of digital competencies in countries. Examples thereof include coding courses for teachers and students implemented in Rwanda by Germany and other stakeholders in 2016[60] and the international online forum Code Club, supported by the Raspberry Pi Foundation, a charity based in the United Kingdom. This organization works with institutions in over 100 countries to provide training materials for educators and volunteers around the world to teach children how to code.[61]

49. Collaboration among Governments, businesses and other stakeholders can also help build ICT infrastructure; accelerate the development of digital skills; build storage and analysis capabilities; and develop regulations and ethics in data collection, usage and open access. For instance, Uganda built an information access centre with the assistance of the Government of Korea to facilitate e-government initiatives.[62] Partnerships such as "EQUALS" – a global partnership for gender equality, led by ITU and the United Nations Entity for Gender Equality and the Empowerment of Women, can also play a useful role in this regard.[63]

50. Also, multi-stakeholder forums such as the Commission on Science and Technology for Development, can contribute to exploring technological advances and their policy implications for countries in terms of capacity-building. In addition, they can facilitate and promote formal collaboration between countries and stakeholders' groups, as well as facilitate the exchange of good practices and lessons learned in promoting digital competencies.

[57] https://news.microsoft.com/en-gb/2017/01/26/microsoft-launches-digital-skills-programme-for-the-uk/ (accessed 27 February 2018).

[58] https://www.apple.com/uk/swift/playgrounds/ (accessed 27 February 2018).

[59] Contribution from the Government of Portugal, available at http://unctad.org/meetings/en/Contribution/CSTD_2018_IPanel_T2_DigitalComp_con21_Portugal_en.pdf (accessed 27 February 2018).

[60] Contribution from the Government of Germany, available at http://unctad.org/meetings/en/Contribution/CSTD_2018_IPanel_T2_DigitalComp_con17_Germany_en.pdf (accessed 27 February 2018).

[61] https://www.codeclubworld.org/about/countries/ (accessed 27 February 2018).

[62] Contribution from the Government of Uganda, available at http://unctad.org/meetings/en/Contribution/CSTD_2018_IPanel_T2_DigitalComp_con24_Uganda_en.pdf (accessed 27 February 2018).

[63] https://www.equals.org/(accessed 27 February 2018).

V. Suggestions for consideration by Member States, the international community and the Commission on Science and Technology for Development at its twenty-first session

51. Digital technologies are already producing an impact on many areas of social and economic life, including employment opportunities. The deployment of existing and emerging technologies offers potential to support the achievement of the 2030 Agenda for Sustainable Development, particularly in areas such as health, education, agriculture, new enterprise development, gender equality and environmental sustainability. However, rapid technological change also creates concerns and challenges, since new technologies can also increase inequalities. Building digital competencies can help countries maximize the benefits and reduce the negative effects of new technologies in societies.

52. Member States are encouraged to take the following steps:

(a) Implement initiatives and programmes that encourage and facilitate investment and labour participation in the digital economy. These include training (for example, digital entrepreneurship), online platforms, community activities, financial incentives (for example, tax breaks and low-interest bank loans), funding for small and medium-sized enterprises engaged in digital technology, promotion of e-business and entrepreneurship, and automation or digitalization of existing businesses;

(b) Implement policies aimed at establishing adequate ICT infrastructure. These include promoting investment in infrastructure and data resource capabilities, including facilities for data collection, storage, and transmission; capabilities for big data analysis and decision-making; and appropriate tools to provide and benefit from open government data;

(c) Incorporate the provision of digital competencies and complementary soft skills, including entrepreneurship, in formal education curricula and lifelong learning initiatives. This should take into consideration best practices, local contexts and needs, and ensure that education is technology neutral;[64]

(d) Promote the study of science, technology, engineering and mathematics, particularly among female students, while also recognizing the importance of studies that incorporate the arts within traditional technical subjects. Training also should be provided to teachers, particularly in areas such as digital skills and computational thinking. Capacity-building in these areas can be provided in combination with training in other general skills, such as entrepreneurship and soft skills, and should consider mandatory training in gender bias awareness;

(e) Support firms and other stakeholders in the provision of training of broad digital competencies for the workplace and in wider social life, lifelong learning capabilities and entrepreneurship skills. Collaboration among stakeholders, including public–private partnerships, should be promoted to support infrastructure development, and the building of data facilities. Special attention should be devoted to policies and partnerships that target the creation and strengthening of digital competencies and skills in youth and women;

(f) Implement support mechanisms to identify trends in ICT development and skills needs, such as foresight, that help workers meet current and emerging demands for competence, and help workers and enterprises adapt to change;

53. The international community may wish to consider the following suggestions:

(a) Foster closer collaboration among different international organizations and with civil society organizations to create initiatives that aim to build digital skills, including hackathons, workshops and other interactive forums;

(b) Identify ICT infrastructure requirements that enable meaningful training in digital skills and competencies;

[64] In other words, education that does not promote specific technologies.

(c) Promote the use of digital methods, such as online platforms for international knowledge sharing and capacity-building.

54. The Commission may wish to consider the following suggestions:

(a) Strengthen the Gender Advisory Board, particularly with respect to building digital competencies, in collaboration with relevant United Nations entities focusing on digital technologies and gender;

(b) Foster closer international cooperation to build linkages in academia across different countries, particularly to create opportunities for students in developing countries to go on exchange programmes in other countries with sophisticated education systems, as well as for commercialization innovations from research institutions in developing countries;

(c) Support the provision of training programmes for policymakers in interdisciplinary topics related to technological change and its development implications and facilitate dialogue between policymakers and science counterparts to keep them abreast of technological developments and their impacts;

(d) Support efforts to build capacity to develop, use and deploy new and existing technologies in developing countries, particularly in the least developed countries;

(e) Support countries in their efforts to identify future trends in terms of capacity-building needs, including through foresight exercises;

(f) Encourage knowledge sharing between Member States and other stakeholders, not only about best practices and success stories, but also about failures and challenges associated with building digital competencies.